63-2-4

296 885

HERO SUPPORTING STUDIES

by

Norman P. Faunce
Paul F. Mohrbach

October 1 to October 31, 1962

Prepared for

U. S. NAVAL WEAPONS LABORATORY
Dahlgren, Virginia

Contract No. N178-8102

THE FRANKLIN INSTITUTE

LABORATORIES FOR RESEARCH AND DEVELOPMENT

PHILADELPHIA   PENNSYLVANIA

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Monthly Progress Report   P-B1980-4

HERO SUPPORTING STUDIES

by

Norman P. Faunce
Paul F. Mohrbach

October 1 to October 31, 1962

Prepared for

U. S. NAVAL WEAPONS LABORATORY
Dahlgren, Virginia

Contract No. N178-8102

ABSTRACT

Preliminary evaluations of protected MARK 7 MOD 0 ignition element plug assemblies indicate losses of 1.43 and 3 db respectively at 80 and 200 mc. These estimates are derived from analysing the component as an equivalent symmetrical T-network; the parameters of the network are derived from measurements of open and short circuit input impedance. Though the resulting estimates appear high, the method warrants further study.

A constant current functioning test of this element shows it to be more sensitive than its unprotected counterpart; it requires only 7.8 amperes compared to 9.2 amperes @ 0.1 msec for 50% functioning. Dynamic resistance which ranges from 55 ohms/second at 3 amperes input to 956 ohm/second at 10 amperes was determined also for the protected MARK 7 element. Its thermal time constant was found to be 11.6 msec.

Additional investigations into means for measuring power to the base of an arbitrary termination proceeded along the line of comparing differential power measurements to measurements derived from detecting the maximum and minimum voltages on a slotted line preceding the load. This latter technique, called the voltage min-max method, appears to be superior to any new technique tried to date.

SUMMARY

Impedance measurements made of the input to the protected MARK 7 MOD 0 plug assembly have been continued. From determinations of this impedance with the bridge side of the assembly first shorted and then opened we obtain data to specify a symmetrical T-network model of the unit. Including the bridge wire terminations as a pure resistance (reasonably valid up to 200 mc) we then compute the theoretical terminated loss. Results indicate essentially no loss up to 30 mc, but at 80 mc we predict 1.43 db loss and at 200 mc it appears to be 3.0 db. Compared to the predicted attenuation based upon the lossy material's characteristics these estimates are high. However, we seem to have hit close enough to warrant additional investigation.

A constant current test was performed with a pulse of 0.1 millisecond duration. For 50% probability of functioning, according to these test results, only 7.8 amperes are necessary. This indicates the protected MARK 7 to be more sensitive than the standard, which requires 9.21 amperes for the same response. Measurements were made of the quantity, dr/dt for the protected plug. At 3 amperes the rate of change of resistance with time is 55 ohms/per second, over intervals of about 816 microsecond or less. At the other extreme, 10 amperes, the resistance change with time is 956 ohm/per second, valid under 123 microsecond. Values between these test end points are almost linearly dispersed. The thermal time constant was determined for this unit and found to be 11.6 millisecond on the average. This is the time for the bridgewire temperature to drop to 36.8% of its initial value.

Additional studies of better means to measure power to the base of an arbitrary termination now involve comparing two likely methods. The differential power method discussed in the previous report is compared with a new approach, the voltage min-max method. In this latter method a calibrated voltage probe is used with a slotted line to determine the maximum and minimum voltage in the line. With these data and knowledge of the characteristic impedance of the line we readily determine power from the expression,

$$P = \frac{V_{max} \, V_{min}}{Z_o}$$

With the MARK 1 MOD 0 Squib as termination, it appears that this new method has great possibilities. From the data, we have determined the loss introduced by the directional coupler to be about 1 db at 3000 mc, and the loss in the base of the plug about 12 db. Using the slotted line permits the power to be determined at a number of points in the systems, which may prove valuable in estimating system losses when they become more significant.

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

P-B1980-4

1. COMPONENT TESTING

Initially, impedance measurements were considered for the primary purpose of specifying the reflection coefficient to be expected when the protected elements were mounted at the end of a 50-ohm transmission line. This information collected last month would give us insight into the problem we might expect in measuring power while performing RF sensitivity evaluations. Work performed this period indicates that we might be able to deduce an estimate of probable firing sensitivity from additional impedance data collected on a minimum number of items.

This period we conducted most of the dc evaluations outlined for the protected MARK 7 MOD 0 ignition element: a constant current test at 0.1 msecond, evaluation of dr/dt and, in addition, determination of thermal time constant. The remaining dc evaluation, a long-time exposure to a non-initiating pulse followed by a dc test to determine if sensitivity is altered, will be conducted when the companion RF test is scheduled.

1.1 RF Evaluation of Protected MARK 7 MOD 0 Ignition Element; impedance Study

Last month we measured the input impedance of a number of protected MARK 7 MOD 0 ignition elements. These data were collected at a number of frequencies and included measurements on both complete units and bridged plug assemblies. Results indicated that the impedance of the total item was duplicated by the impedance of the plug only, at least up to a frequency of 500 Mc.

While determining these impedances we conceived the idea that we might, by making additional measurements, collect data from which we could predict the RF loss for the assembly. Consequently, we now propose that the plug be represented as an equivalent T-network, in

- 1 -

which form we can calculate the ratio of power dissipated in the plug to that dissipated in the bridge wire.

Any unknown network can be represented as an equivalent T; the transformations of measurements are given in Figure 1-1. Because of its geometry we might best characterize the protected MARK 7 plug as a non-symmetrical T-network. However, to minimize the effort initially we assumed it to be symmetrical. Accordingly, we determined the input impedance of two separate plug assemblies with their outputs alternately open and shorted. Using average values from these measurements we determined the equivalent T network impedances. These data are all included in Table 1-1. The input impedance of the bridge plug (average of 5 units) is also included for comparison.

Assuming the network to be terminated by a 1 ohm bridge wire we computed the ratio of power dissipated in the termination to power dissipated in the total assembly (total power input). The values in Table 1-1 labelled base loss are equal to ten times the logarithm (base 10) of this power ratio. The two results of greater than zero magnitude are plotted in Figure 1-2, which includes a point of 5.73 db at 500 Mc representing the average attenuation evaluated for this lot of protected elements during their development.

These three data points appear to define a straight line. Had the slope of this line been 53° we would have reason to be exceedingly optimistic about the technique used to obtain the data; 53° is the slope of the attenuation-frequency characteristic determined for the attenuating material used in the protected plug development.

The fact that we determined terminated power loss from these data would account in some measure for the seemingly high loss values. By extrapolating the curve we would predict a value of about 0.65 db at 30 Mc; our calculations indicated the loss at this frequency to be exceedingly low, nearly zero. Because of these inconsistencies we must

$$Z_{11} \quad \text{UNKNOWN NETWORK} \quad Z_{22}$$

$$Z_1 \qquad Z_3$$

$$Z_2 \qquad \text{EQUIVALENT "T" NETWORK}$$
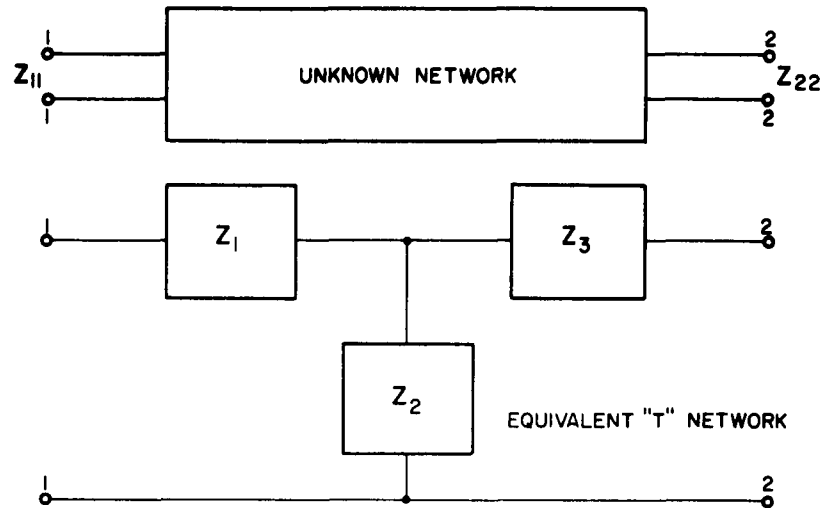
	Non-Symmetrical	Symmetrical
Z_1	$Z_{110} - Z_2$	$Z_{110} - Z_2$ $Z_{220} - Z_2$
Z_2	$\sqrt{Z_{110}\,(Z_{220} - Z_{22S})}$ $\sqrt{Z_{220}\,(Z_{110} - Z_{11S})}$	$\sqrt{(Z_{110})^2 - Z_{110}\,Z_{11S}}$ $\sqrt{(Z_{220})^2 - Z_{220}\,Z_{22S}}$
Z_3	$Z_{220} - Z_2$	$Z_{110} - Z_2$ $Z_{220} - Z_2$

$Z_{110} = Z_{11}$ with 2-2 open; $Z_{11S} = Z_{11}$ with 2-2 shorted

$Z_{220} = Z_{22}$ with 1-1 open; $Z_{22S} = Z_{22}$ with 1-1 shorted

FIG. 1-1 "T" NETWORK MODEL OF UNKNOWN NETWORK

Table 1-1

IMPEDANCE MODEL AND BASE LOSS DETERMINED FOR
PROTECTED MARK 7 MOD 0 PLUG

Frequency (mc)	Z_{in}	Z_{oc}	Z_{se}	Z_1	Z_2	Base Loss (db)
		(ohms)				
3	0.98+j0	102-j66.7	0+j0	~0	97-j66.7	0
7.6	0.95+j0.39	49-j65.8	0+j0.6	~0	49-j65.6	0
30	0.98+j1.3	11.8-j28	0+j1.2	0.01+j0.6	11.8-j28.6	0
80	2.0+j5.0	4.3-j15	1.0+j4.5	0.4+j2.2	3.9-j17.2	1.43
200	6.0+j6.5	3.0-j4.5	3.0-j6.5	0.76+j2.86	.24-j7.16	3.0
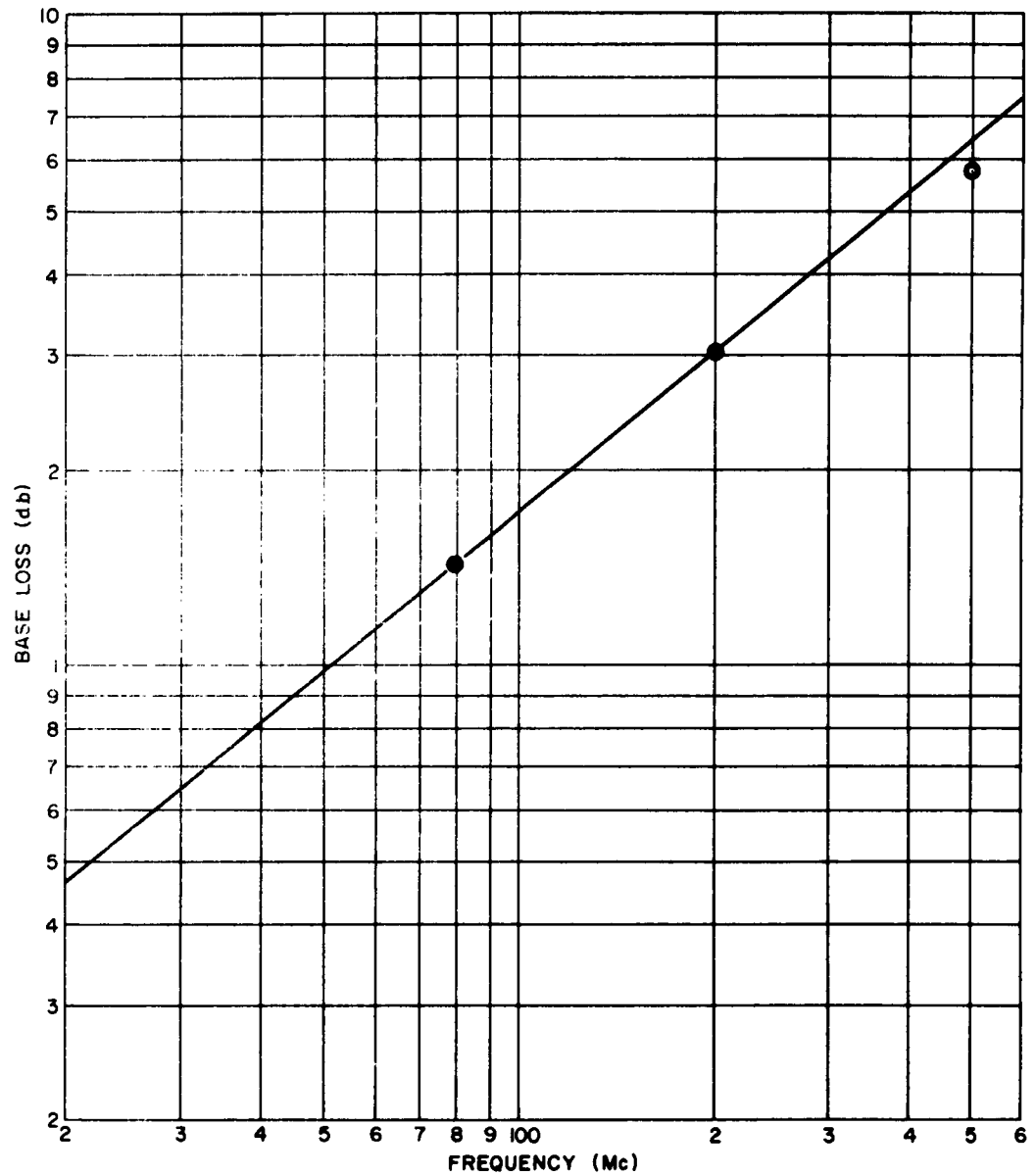
FIG. 1-2. BASE LOSS OF PROTECTED MARK 7 MOD 0 IGNITION ELEMENT

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

be doubtful of the reliability of this technique. However, since we seem to have missed by such a relatively narrow margin it seems advisable to make another trial. During the next period we will re-appraise this technique giving thought to the merits of describing the non-symmetrical model.

1.2 DC Evaluation of Protected MARK 7 MOD 0 Ignition Element

1.2.1 Constant Current Test at 0.1 millisecond

When the RF protected lot of MARK 7 MOD 0 ignition elements was produced in late 1959 two constant current evaluation tests were performed. At that time, it was intended to show that the protected plug with its low dc resistance would not seriously alter normal functioning of the completed ignition element. The shortest time used was 1.0 millisecond. We have completed an additional constant current test during this period using a pulse of 0.1 millesecond. The data sheet for this test is appended. Results are given in Table 1-2 contrasted to similar data for the unprotected (standard) ignition element. These data show that the incorporation of the attenuator has not adversely altered the items normal functioning sensitivity.

Table 1-2

CONSTANT CURRENT SENSITIVITY (0.1 MILLISECOND) OF PROTECTED
AND STANDARD MARK 7 MOD 0 IGNITION ELEMENT

	Current for 50% Firing Prob. (amps)	(log units)	Std. Dev. (log units)	Pulse Dura. (msec)	Sample Size
Protected	7.807	.89249	.01357	0.100	40
Unprotected (Standard)	9.21	0.96412	.0164	0.100	41

1.2.2 Dynamic Resistance

Dynamic resistance characteristics of the protected MARK 7 were determined by passing constant current through the bridge wire and recording the voltage across the bridge as a function of time. These measurements, for input currents of from 3 to 10 amperes, are summarized in Table 1-3. Variation of $\frac{dr}{dt}$ with current is shown in Figure 1-3. When using these data in computing resistance, it is recommended that exposure time (Δ T) be not longer than that indicated by the time curve included in Figure 1-3. Extrapolation for longer intervals will tend to show higher resistance than the true value since it does not take into account the cooling effect of the bridgewire environment.

Figure 1-4 depicts a typical trace of voltage vs. time due to a current through the bridge wire on which measurements of dynamic resistance were made.

1.2.3 Thermal Time Constant

The thermal time constant is defined as the time required for the bridgewire temperature to decay to 36.8% of the maximum temperature excursion after application of an input stimulus that does not cause the item to explode.

The thermal time constant of the protected MARK 7 was determined in the following manner. A current whose magnitude was small enough not to cause appreciable changes in the bridgewire and its environment was passed continuously through the bridgewire of the device before, during, and after application of a large current pulse of short duration (7 amperes for 100 us). The monitoring current was held constant by the inclusion of a large current limiting resistor.

Since the monitoring current was constant, it was possible to use the potential across the bridgewire (observed with an oscilloscope) as a measure of the instantaneous value of resistance as the item cooled after application of the relatively large current pulse.

Table 1-3

DYNAMIC RESISTANCE MEASUREMENTS OF THE
PROTECTED MARK 7 MOD 0 IGNITION ELEMENT

Item No.	Input Current (amps)	Resistance Change ΔR (ohms)	Time interval at Resistance Change Δt (μ sec)	$\frac{\Delta R}{\Delta t}$ ohms/sec	(Averages) $\frac{\Delta R}{\Delta t}$ ohms/sec	$\overline{\Delta t}$ μ sec
1		0.047	910	52		
2		0.083	870	95		
3		.067	800	84		
4	3.0	.037	970	38	55	816
5		.015	360	43		
6		.027	900	30		
7		.039	900	43		
8		.080	370	216		
9		.060	360	167		
10		.080	420	190		
11	5.0	.080	380	211	217	382
12		.080	360	222		
13		.100	400	250		
14		.100	385	260		
15		.080	380	222		
16		.130	172	756		
17		.100	176	568		
18	7.5	.093	160	581	582	158
19		.069	160	431		
20		.069	120	575		
21		.110	120	917		
22		.110	110	1000		
23	10.0	.115	112	1027	956	123
24		.120	132	909		
25		.130	140	929		
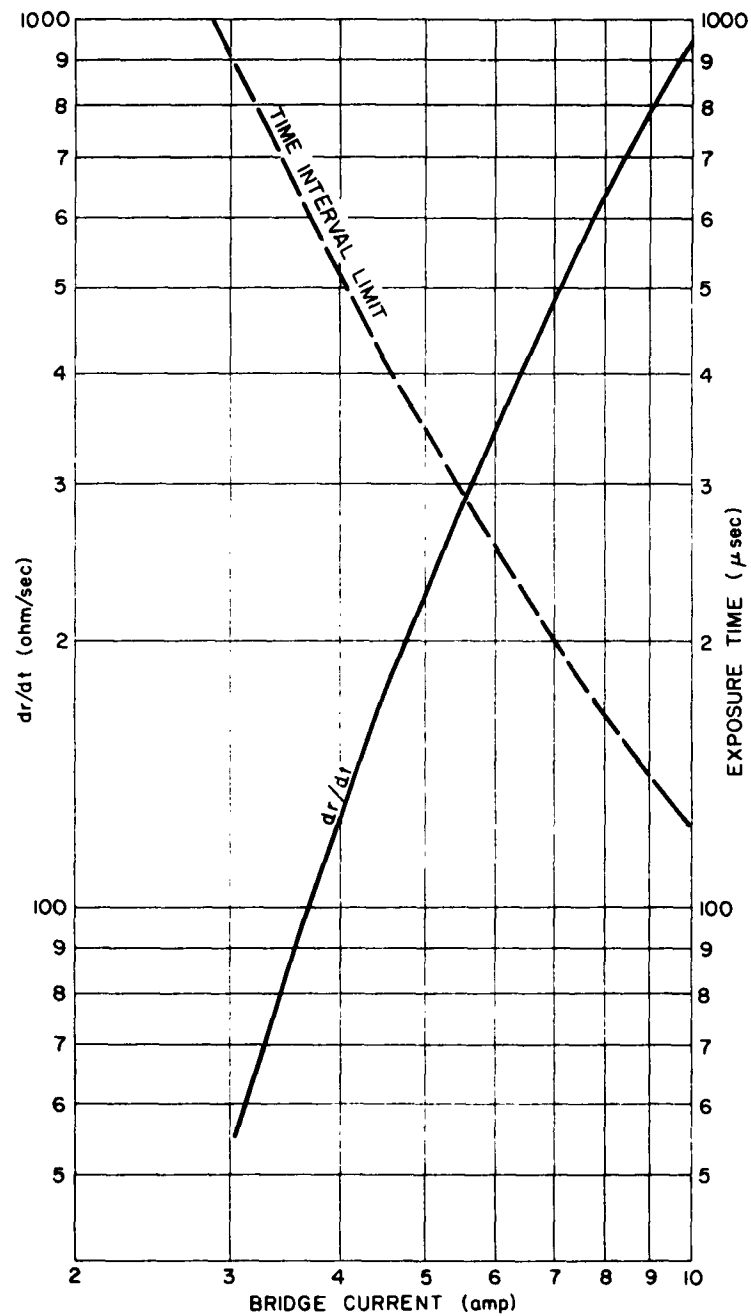
FIG. I-3. DYNAMIC RESISTANCE OF PROTECTED
MARK 7 MODO IGNITION ELEMENT
(Under Quasi Adiabatic Conditions)

$V \approx R$

INPUT CURRENT = 3 amps
HORIZONTAL DEFLECTION = 100 μsec/division
VERTICAL DEFLECTION = 0.2 volts/division

$\longleftarrow$ t
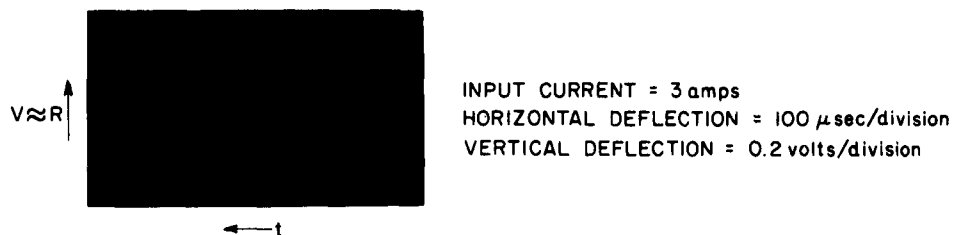
FIG. I-4. TYPICAL TRACE FOR DETERMINING DYNAMIC RESISTANCE

$V \approx R$

HORIZONTAL DEFLECTION = 5 msec/division
VERTICAL DEFLECTION = 1 mvolts/division
MONITORING CURRENT = 125 mamp
τ = TIME FOR E TO DECAY TO E_0/e
τ = 12 msec

$\longleftarrow$ t
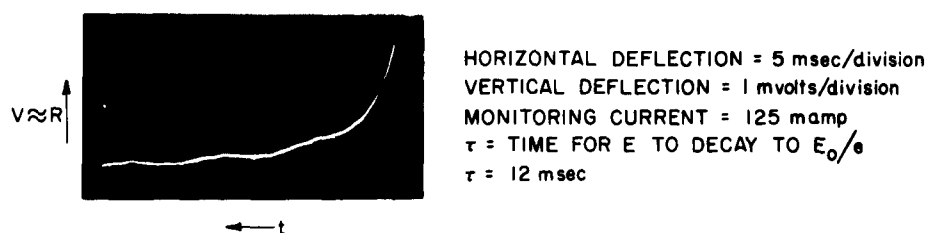
FIG. I-5. TYPICAL TRACE FOR DETERMINING THERMAL TIME CONSTANT

A typical oscillogram is shown in Fig. 1-5. The circuit used
for these measurements is given in Fig. 1-6. Results of these tests
appear in Table 1-4. Values range from 8.5 to 14.0 milliseconds, the
grand average being 11.6.

$\longrightarrow$ $\longleftarrow$ t = 100 μ sec
7 amp

PULSE FORMING NETWORK

SCOPE

CURRENT LIMITING RESISTOR

MONITORING CURRENT 125ma

MK-7
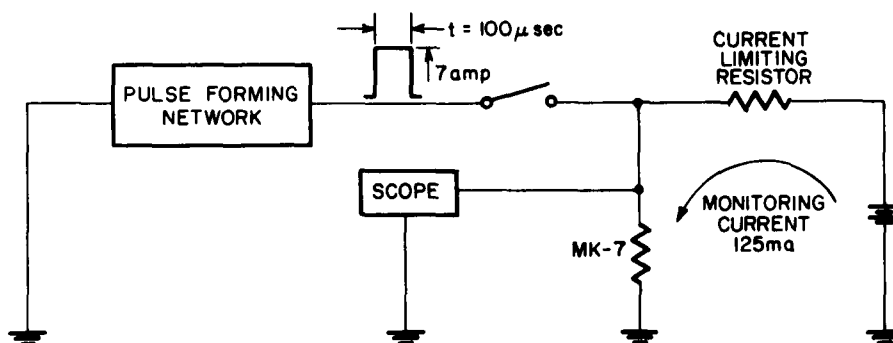
FIG. I-6. CIRCUIT FOR DETERMINING THERMAL TIME CONSTANT

Table 1-4

THERMAL TIME CONSTANT OF PROTECTED MARK 7
MOD O IGNITION ELEMENT

Item No.	Time Constant T (msec) (three readings)			Ave
1	11.8	10.8	11.5	11.4
2	14.0	13.0	12.5	13.2
3	12.0	11.0	12.0	11.9
4	12.0	12.0	11.0	11.7
5	14.0	13.0	13.0	13.3
6	9.0	9.5	12.0	10.2
7	8.5	9.0	11.0	9.5
8	12.0	10.0	10.0	10.7
9	11.0	11.0	12.0	11.3
10	13.5	12.5	13.0	13.0

Grand Average   11.6

2. COMPONENT DEVELOPMENT

No work has been done on this phase during this period.

3. INSTRUMENTATION-POWER MEASUREMENTS BY
VOLTAGE PROBE TECHNIQUE

Experimental results of our first attempt at evaluation of a differential power measurement technique, at 3 and 10 Gc, were given in the previous report. The data obtained was not completely conclusive; and the work has been continued in the hope of resolving some of the conflicts appearing during the first tests.

We were fortunate in being able to combine into one experiment additional tests with the differential power technique and initial tests with a slotted transmission line and calibrated traveling probe. This slotted line and traveling probe technique, while generally known, is not a commonly used method for measuring net power to a load. Preliminary investigations have indicated that this method may be of greater value to our work than the differential power method.

3.1 Basis of Probe-in-Slotted Line Method

This technique is clearly outlined in section 3-88 of the "Handbook of Electronic Measurements,"[1]. A part of the text is quoted:

"The power is also given by

$$P = \frac{V_{max} V_{min}}{Z_o} = \frac{V_{max}^2}{SZ_o} = \frac{SV_{min}^2}{Z_o}$$

where V_{max} is the RMS voltage at a point of voltage maximum and V_{min} is the RMS voltage at a point of voltage minimum on the line.

$$S = \frac{V_{max}}{V_{min}}$$

The probe may be calibrated with known powers into a matched load and then used to measure the pertinent quantities in this equation. The voltage calibration then includes the characteristic impedance of the line, and the equation may be directly applied to the measurement of power delivered to the load."

This discussion suggests procedures which are highly applicable in our present RF work. First, a method for calibrating a crystal probe

(1) <u>Handbook of Electronic Measurements</u> VOL. I, edited by Moe Wind; Polytechnic Institute of Brooklyn, Microwave Research Institute; Contract Nos. AF-30(602)-677 and AF-30(602)-1578. (Quotation from section 3-88).

as a true RMS volt meter is implied. Secondly, using this calibrated
probe, the values of maximum and minimum voltage read at points a
quarter-wavelength apart on the line may be combined with the known
characteristic impedance of the slotted line to obtain the net power
toward the load. However, the effective point of measurement will still
be some distance from the load. Under the most ideal conditions the
first point of measurement is expected to be a voltage maximum approximately
1/4 wavelength away from the load and the companion measurement will
occur at an additional 1/4 wavelength distance. However, we envision
refinements which will allow us to estimate the power lost in the
sections of transmission line between the load and the point where we
effectively measure power. This will permit us to quote powers at the
base of the termination, independent of systems losses.

3.1.1 Voltage Calibration of the Slotted Line Probe

We experienced no particular difficulties in calibrating the
crystal probe in the carriage of a Hewlett-Packard 805A slotted line
at 3 Gc. A Hewlett-Packard 434A calorimeter was an ideal self-indicating
termination for the slotted line. Figure 3-1 is a block diagram of the
requirements for the calibration.

With a fixed power output from the generator we record the
microvolt meter reading and calorimeter indication. Since the
calorimeter is 50 ohms and is terminating a 50 ohm system we expect a
flat line. Actually there was a small residual VSWR, therefore for each
power setting we recorded both the maximum and minimum voltage along the
slotted line. For a flat lossless line the voltage (V) everywhere
along it is related to the power (P) dissipated in the termination (R)
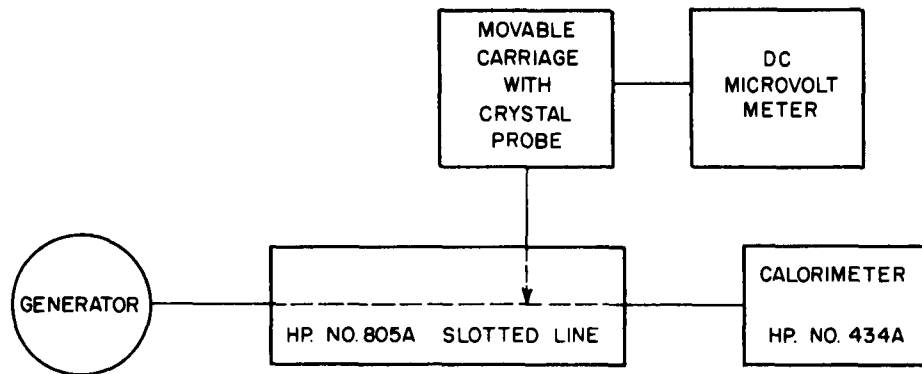by

$$V = \sqrt{PR}.$$

FIG. 3-1. SYSTEM FOR CALIBRATION OF CRYSTAL PROBE

We computed the value of the radical for the various power levels at which we recorded data and assigned this new value to the voltmeter reading. In this manner we obtained the calibration shown in Figure 3-2. Because of the residual VSWR we obtain two voltages for each power; the calibration curve is drawn as a visual average of the points.

3.1.2   Measurements of Power by Voltage "Min-Max" Method

With the travelling probe calibrated as described in this preceding paragraph, we are prepared to measure power for any arbitrary termination. Actually, the power measured in this manner is the power flowing toward the termination at a point in the transmission system located between the points of measurement. Working at 3000 Mc with a MARK 1 MOD 0 as termination, we found that we could obtain three voltage minimums and maximums alternately spaced along the slotted line. Thus we may determine the power flow at three equally spaced points along the line. If the line is relatively lossy we should note a significant difference between power measured at these points, decreasing as we approach the load. If they show little difference we
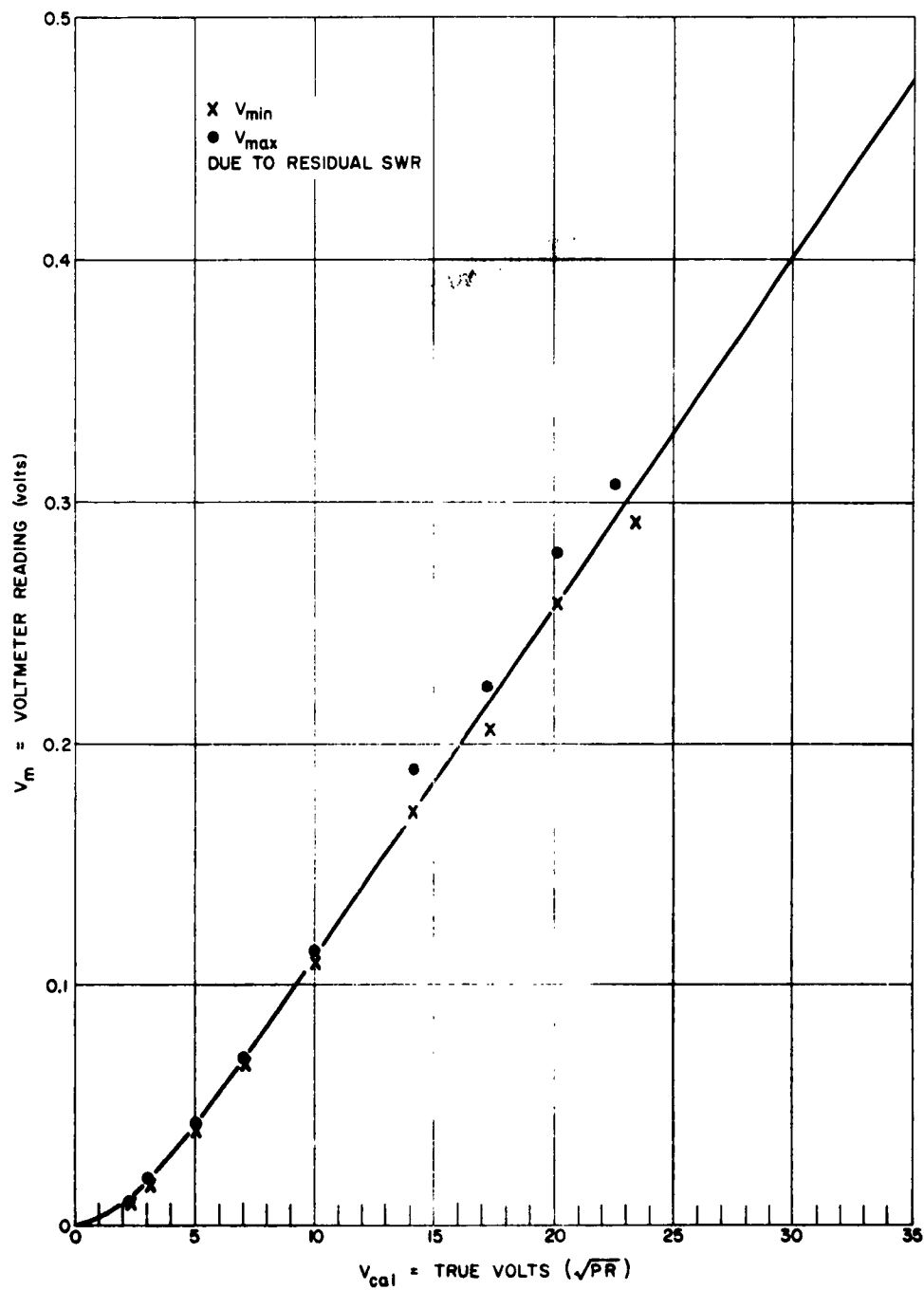
FIG.3-2. VOLTAGE POWER CALIBRATION
(Calorimeter as Load – 3000 Mc)

may assume the system to be relatively lossless, and the power flowing in the line should be the power dissipated in the termination.

A number of measurements were made by this technique and by the differential power method discussed last period. Details and results are given in the next section.

3.2 Differential Power and Voltage "Min-Max" Power Measurements Compared

With a MARK 1 MOD 0 squib plug as termination we endeavored to measure the power input to its base by both of the methods we have just discussed. So as to have a direct comparison of the two systems, we made both measurements simultaneously by placing the measuring equipment in series. Because each technique effectively measures the power flow at one point in the transmission line, the system placed farthest away from the load will indicate the power dissipated in the load plus the power absorbed by the other measuring system. In view of this we made two determinations, first with the dual directional coupler (differential power) nearest the load, then with the measurement systems interchanged. The two alternate system arrangements are shown in Figure 3-3, and the results are given in Tables 3-1 and 3-2.

For measurements of differential power the calibration procedure detailed in the previous month's report was used. The forward port output was found to give an indication of 9.44 mw per watt of main line forward power and the reflected port 9.62 mw/watt of reflected power. The calibration given in Figure 3-1 was used for reducing the voltage min-max data.

At 3000 Mc the slotted line was long enough to enable us to collect three pairs of min-max voltages, and we took full advantage of this condition. Since there did not appear to be any definite indication of a smooth decrease in power along the line we merely averaged the three results.
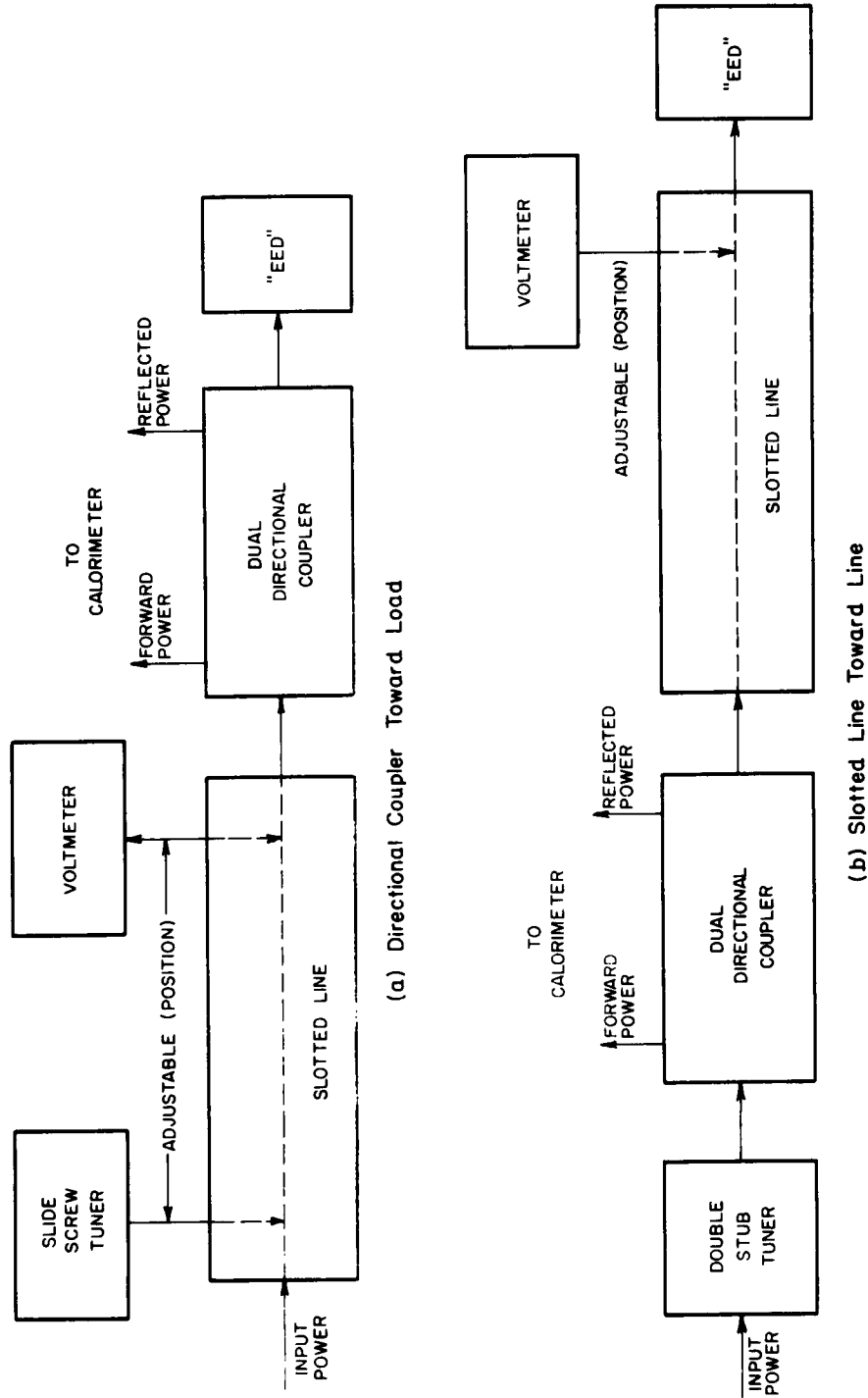
(a) Directional Coupler Toward Load

(b) Slotted Line Toward Line

FIG. 3-3. EQUIPMENT ARRANGEMENTS FOR POWER MEASUREMENTS

Table 3-1

POWER MEASUREMENTS DATA

(Differential Power Nearest Load)

Input Power (watts)	Voltage Min-Max Measurements							Differential Power Measurements						
	Minimum Reading	V min (volts)	Maximum Reading	V max (volts)	VSWR	V max V min (volts^2)	Net Power To Load (watts)	Ave. Net Power (watts)	Forward Port (mm)	Foward Power (watts)	Reflected Port (mm)	Reflected Power (watts)	Net Pwr to Load (watts)	Photocell Output
2.7	.034	4.4	.440	32.4	7.36	142.5	2.65	2.77	56	5.29	29.5	2.54	2.75	25
	.030	4.0	.440	32.4	8.10	129.6	2.59							
	.033	4.33	.435	32.x	7.39	138.6	2.77							
2.4	.027	3.78	.405	29.8	7.88	112.6	2.25	2.14	46	4.38	25.0	2.15	2.23	10
	.024	3.50	.400	29.6	8.45	103.6	2.07							
	.025	3.60	.395	29.3	8.14	105.5	2.11							
1.9	.022	3.32	.375	27.8	8.37	92.30	1.85	1.73	41.5	3.92	22.5	1.94	1.98	4.5
	.019	3.02	.370	27.5	9.40	83.05	1.66							
	.020	3.13	.360	26.8	8.56	83.88	1.68							
1.5	.019	3.02	.340	25.5	8.44	77.01	1.54	1.41	33.5	3.16	19.0	1.64	1.52	
	.016	2.72	.330	24.8	9.12	67.45	1.35							
	.0165	2.75	.325	24.5	8.91	67.37	1.35							

Table 3-2

POWER MEASUREMENTS DATA
(Min-Max Power Nearest Load)

Input Power (watts)	Differential Power Measurements					Voltage Min-Max Measurements								Ave. Net Power (watts)	Photocell Output
	Forward Port (mw)	Forward Power (watts)	Reflected Port (mw)	Reflected Power (watts)	Net Power to Load (watts)	Minimum Reading	V_{min} (volts)	Maximum Reading	V_{max} (volts)	VSWR	$V_{max}\,V_{min}$ (volts^2)	Net Pwr to Load (watts)		
2.8	54	5.08	28.5	2.45	2.63	.0240	3.5	.420	31.0	8.85	108.5	2.17	2.19	25
						.0255	3.55	.420	31.0	8.73	110.1	2.20		
						.0255	3.55	.420	31.0	8.73	110.1	2.20		
2.4	47	4.44	25.2	2.17	2.27	.021	3.21	.385	28.6	9.19	91.81	1.84	1.87	14
						.0215	3.28	.390	28.8	8.78	94.46	1.89		
						.0215	3.28	.390	28.8	8.78	94.46	1.89		
1.9	38.5	3.63	21.0	1.81	1.81	.0165	2.76	.354	25.9	9.38	71.48	1.43	1.44	—
						.0170	2.82	.343	25.7	9.11	72.47	1.45		
						.0170	2.82	.343	25.7	9.11	72.47	1.45		
1.5	30.5	2.88	18.5	1.59	1.27	.0124	2.34	.305	23.2	9.91	54.29	1.09	1.10	—
						.0130	2.38	.305	23.2	9.75	55.22	1.10		
						.0130	2.38	.305	23.2	9.75	55.22	1.10		

For ease in comparison we have extracted the essential data
from the detailed tabulations and presented it in summary form in Table
3-3. The voltage min-max power measurement is the lower value of the
two simultaneous determinations whether or not it is measured nearest
the load. The differential power measurements seem to be constant for
any one system input power without regard to this sequence of the
equipment. This 　 us to surmise that the slotted line is essentially
lossless, and the dual directional coupler introduces about 20% loss, or
roughly 1 db.

For a Clairex cell reading of 25, dc power to the bridge wire
is about 150 mw. Assuming that 1000 Mc power would produce nearly the
same cell 　 as dc, and further assuming the min-max power to be
the actual power input to the device, we can estimate the base loss,
which comes out to be about 11.7 db; using differential power we would
predict a loss of about 12.6 db. It is interesting to note that these
predictions differ by about 1 db, or the amount of loss associated with the
dual directional coupler.

These results do not allow us to conclude that we have, in
fact, measured the power to the base of the device unless we can assume
the transition between the slotted line and the load to be lossless.
Since our data indicate a relatively low VSWR (~8 to 10) we may be
justified in making such an assumption. Nevertheless, we will explore
other means to validate the technique. We will attempt its validation
　 for the case of high VSWR and correspondingly high system losses.
Toward this end we will examine the possibility of the voltage min-max
method being usable at 1000 Mc to determine the power to the base of
the MARK 1 MOD 0. Previous experiments suggest that 　
base differs little from the power at the bridge wire at 1000 Mc,
although the VSWR is on the order of 50.

Table 3-3

SUMMARY OF POWER MEASUREMENTS

Input Power (Watts)	Voltage Min-Max Power (Watts)	Differential Power (Watts)	Photo Cell Output
2.8	2.77	2.75	25
2.4	2.14	2.23	10
1.9	1.73	1.98	-
1.5	1.41	1.52	-

	Differential Power	Voltage Min-Max Power	
2.8	2.63	2.19	25
2.4	2.27	1.87	14
1.9	1.81	1.44	-
1.5	1.27	1.10	-

ACKNOWLEDGEMENTS

P-B1980-4

APPENDIX

CONSTANT CURRENT EVALUATION DATA

for

PROTECTED MARK 7 MOD 0 IGNITION ELEMENT

0.1 msec PULSE DURATION

Functioning Levels (ζ)amp.									FUNCT. TIME	RESISTANCE	ITEM NO.
		7.413	7.562	7.716	7.943	8.128			m.sec.secs	Ω	
			X	X					.566	1.061	1
			X						1.346	1.630	2
			O							1.047	3
			O							.949	4
			O	X					244	1.036	5
			X						361	1.066	6
			O							.988	7
			O							1.009	8
				O	X				3.471	.945	9
				O						.957	10
				O						.574	11
				X					260	.965	12
				O						.965	13
				X					561	1.057	14
				O						.944	15
					X					.911	16
					O				341	1.002	17
					O					.912	18
					O				2.713	.993	19
					O					1.002	20
					X				231	1.018	21
				X	X				1.942	1.004	22
				X					478	.976	23
				O						.974	24
			O	O						1.110	25
				X					360	1.030	26
				O						1.012	27
				X					329	.998	28
				O						1.055	29
				X					223	1.101	30
				O						1.023	31
				X					243	1.030	32
				O						1.009	33
			O							1.102	34
			O							1.041	35
				X					364	1.067	36
			O							.998	37
				O						1.078	38
				X					260	1.009	39
				X					269	1.006	40
											41
											42
											43
											44
											45
											46
											47
											48
											49
											50
									n_x = 20		X
									n_0 = 20		O

i	i²	n_o	n_x	ζ =amp
0	0	2	0	7.413
1	1	5	2	
2	4	9	5	
3	9	4	9	
4	16	0	4	
5	25			
6	36			

Totals: $N_o = 20$ $N_x = 20$

Special Parameters

$c = (\log \zeta)_{i=0} = 0.86999$

$d = (\log \zeta)_{i+1} - (\log \zeta)_i = .01$

Primary Statistics

$A = \Sigma\ i\ n$

$B = \Sigma\ i^2\ n$

$M = (NB - A^2)/N^2$

$m = c + d (A/N \pm \frac{1}{2})^*$

$\sigma = 1.62\ d\ (M + 0.029)\sqrt{\dfrac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for $M \geqslant 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101 1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =	35	55
B =	77	167
M =	.7875	.7875
m =	0.89249	0.89249
σ =	.01357	.01357

Secondary Statistics

$m = \dfrac{N_o\ m_o + N_x\ m_x}{N_o + N_x} = 0.89249$

$\sigma = \sqrt{\dfrac{N_o\ \sigma_o^2 + N_x\ \sigma_x^2}{N_o + N_x}} = .01357$

ζ = Antilog m = 7.807 amp.

DATE	INITIALS	PAGE NO.
10-22-62	T.McK	A1

HUMIDITY — *Room Conditions*

TEMP — *Room Conditions*

LOT NO.

ITEM — T.McK-1

FREQUENCY / PULSE WIDTH / REP RATE

TYPE OF TEST — Constant Current

TEST NO.

DISTRIBUTION LIST

U. S. Naval Weapons Laboratory
Dahlgren, Virginia
Attn: Code WHR (2)

Chief, Naval Operations (OP-411H)
Department of the Navy
Washington 25, D.C. (1)

Chief, Bureau of Naval Weapons
Department of the Navy
Washington 25, D.C.
Code: C-132 (1)
Code: RAAV-3421 (1)
Code: RM-15 (1)
Code: RMMO-224 (1)
Code: RMMO-234 (1)
Code: RMMO-32 (1)
Code: RMMO-33 (1)
Code: RMMO-4 (1)
Code: RMMO-43 (1)
Code: RMMO-44 (1)
Code: RMMP-343 (1)
Code: RREN-32 (1)
Code: DIS-313 (4)

Chief, Bureau of Yards and Docks
Department of the Navy
Washington 25, D.C.
Code D-200 (1)

Commander
U.S. Naval Ordnance Laboratory
White Oak, Maryland
Code: ED (1)
Code: NO (1)
Code: LV (1)
Code: Technical Library (1)

Commander
U.S. Naval Ordnance Laboratory
Corona, California
Attn: Code 561 (1)

Commander
U.S. Naval Ordnance Test Station
China Lake, California
Attn: Code 556 (1)
Attn: Code 4572 (1)

Commanding Officer
U.S. Naval Air Development Center
Johnsville, Pennsylvania
Code: EL 94 (1)

Officer-in-Charge
U.S. Naval Explosive Ordnance Disposal
Technical Center
U.S. Naval Propellant Plant
Indian Head, Maryland (1)

Commanding Officer
U.S. Naval Underwater Ordnance Station
Newport, Rhode Island (1)

Director
U.S. Naval Research Laboratory
Washington 25, D.C.
Code: 5410 (2)

Commandant of the Marine Corps
Washington 25, D.C.
Code: AO4C (1)

Commander
Pacific Missile Range
P.O. Box 8
Point Mugu, California
Attn: Code 3260 (1)

Commanding Officer and Director
U.S. Navy Electronics Laboratory
San Diego 52, California
Attn: Library (1)

Commanding Officer
U.S. Naval Ammunition Depot
Crane, Indiana
Attn: Code 34 (1)

DISTRIBUTION LIST (Cont.)

Commanding Officer
U.S. Naval Ordnance Plant
Macon, Georgia
Attn: Code PD 270 (1)

Commander Naval Air Force
U.S. Atlantic Fleet (CNAL 724B)
U.S. Naval Air Station
Norfolk 11, Virginia (1)

Commander Training Command
U.S. Pacific Fleet
c/o U.S. Fleet Anti-Submarine
  Warfare School
San Diego 47, California (1)

Commanding General
Headquarters, Fleet Marine Force, Pacific
c/o Fleet Post Office
San Francisco, California
Attn: Force Communications Electronic
        Officer (1)

Commander in Chief
U.S. Pacific Fleet
c/o Fleet Post Office
San Francisco, California
Attn: Code 4 (1)

Commander Seventh Fleet
c/o Fleet Post Office
San Francisco, California (1)

Commander
New York Naval Shipyard
Weapons Division, Naval Base
Brooklyn 1, New York
Attn: Code 290 (1)

Commander
Pearl Harbor Naval Shipyard
Navy No. 128, Fleet Post Office
San Francisco, California
Attn: Code 280 (1)

Commander
Portsmouth Naval Shipyard
Portsmouth, New Hampshire (1)

Department of the Army
Office Chief of Ordnance
Washington 25, D.C.
Attn: ORDGU-SA (1)
Attn: ORDTN (1)
Attn: ORDTB (Research &
        Special Projects) (1)

Office Chief Signal Officer
Research and Development Div.
Washington 25, D.C.
Attn: SIGRD-8 (1)

Commanding Officer
Diamond Ordnance Fuze Laboratories
Washington 25, D.C.
Attn: Mr. T. B. Godfrey (1)

U.S. Army Nuclear Weapon
  Coordination Group
Fort Belvoir, Virginia (1)

Director
U.S. Army Engineer Research &
  Development Labs.
Fort Belvoir, Virginia
Attn: Chief, Basic Research Group (1)

Commanding Officer
Picatinny Arsenal
Dover, New Jersey
Attn: Artillery Ammunition &
        Rocket Dev. Lab. -
        Mr. S.M. Adelman (1)
Attn: Evaluation Unit,
        Instrumentation Section,
        Building 352 -
        Mr. Abraham Grinoch, (1)

b

DISTRIBUTION LIST (Cont.)

Commanding General
Headquarters 2DRAADCOM
Oklahoma City, AFS
Oklahoma City, Oklahoma (1)

Commanding Officer
U.S. Army Signal Research &
  Development Laboratory
Fort Monmouth, New Jersey
Attn: SIGEM/EL-GF (1)

Commander
U.S. Army Ordnance
Frankford Arsenal
Philadelphia 37, Penna. (1)

Commander
U.S. Army Rocket & Guided
  Missile Agency
Redstone Arsenal, Alabama
Attn: ORDXR-R (Plans) (1)

Commanding Officer
Office of Ordnance Research,
  U.S. Army
Box CM, Duke Station
Durham, North Carolina
Attn: Internal Research Div. (1)

Commanding General
White Sands Missile Range
New Mexico
Attn: ORDBS-G3 (1)

Commanding Officer
White Sands Missile Range, New Mexico
U.S.A. SMSA
Attn: SIGWS-AJ (1)

Commanding General
U.S. Army Electronic Proving Ground
Ft. Huachuca, Arizona (1)

Director of Office of Special
  Weapons Developments
United States Continental
  Army Command
Fort Bliss, Texas
Attn: Capt. Chester I. Peterson
      T S Control Officer (1)

Headquarters
Air Research & Development Command
Andrews Air Force Base
Washington 25, D.C.
Attn: RDMMS-3 (1)

Commander
Air Force Missile Test Center
Patrick Air Force Base, Florida
Attn: Code MTRCF (1)

Director Nuclear Safety
Kirtland AFB, N. M. Research
Attn: AFCNS (1)

Headquarters
Ogden Air Material Area
Hill Air Force Base
Ogden, Utah
Code OOYSS (1)

Commander
Air Force Missile Development
  Center
Holloman Air Force Base
Alamagordo, New Mexico (1)

Griffiss AF Base
RADC, New York
Attn: RCLS/Philip L. Sandler (1)

Commander
Air Force Special Weapons Center
Kirtland Air Force Base
Albuquerque, New Mexico
Attn: SWVSA (1)

DISTRIBUTION LIST (Cont.)

Director of Missile
Safety Research
Deputy IG for Safety
Norton AFB, California (1)

Commanding General
Air Fleet Marine Force, Pacific
MCAS, El Toro
Santa Ana, California (1)

Strategic Air Command
Offutt Air Force Base, Nebraska
Attn: DOSDM (1)

Commander
Headquarters Ground Electronics
  Engineering Installation Agency
Griffiss Air Force Base
Rome, New York
Attn: ROZMWT (1)

Armed Services Explosives Safety Board
Department of Defense
Room 2075, Gravelly Point, Bldg. T-7
Washington 25, D.C. (1)

Headquarters
Armed Services Technical Info.
  Agency (TIPCR)
Arlington Hall Station
Arlington 12, Virginia
Via: U.S. Naval Weapons Laboratory
     Dahlgren, Virginia
     Code WHR (10)

Commander
Field Command
Defense Atomic Support Agency
Albuquerque, New Mexico
Attn: FCDR3 (1)

U.S. Atomic Energy Commission
Division of Military Application
Washington 25, D.C. (1)

Defense Research Staff
British Embassy
3100 Mass. Ave. N.W.
Washington 8, D.C.
Attn: Mr. G. R. Nice
Via: U.S. Naval Weapons Lab.
     Dahlgren, Virginia
     Code WHR (1)

Naval Member
Canadian Joint Staff
2450 Massachusetts Ave. N.W.
Washington 8, D.C.
Attn: Staff Officer (Weapons)
Via: U.S. Naval Weapons Lab.
     Dahlgren, Virginia
     Code WHR (1)

Atlas Powder Company
Reynolds Ordnance Section
P.O. Box 271
Tamaqua, Pennsylvania
Attn: Mr. R. McGirr (1)

The Bendix Corp.
Scintilla Div.
Sidney, N.Y.
Attn: R.M. Purdy (1)

Bermite Powder Company
22116 West Soledad Canyon Road
Saugus, California
Attn: Mr. L. LoFiego (1)

Chance Vaught Corp.
P.O. Box 5907
Dallas 22, Texas
Attn: R.D. Henry (1)

Aerojet-General Corporation
P.O. Box 296
Azusa, California
Attn: Myra Z. Grenier, Librarian (1)

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

P-B1980-4

DISTRIBUTION LIST (Concl.)

Gruman Aircraft Engineering Corp.
Weapons Systems Department
Bethpage, Long Island, New York
Attn: Mr. E.J. Bonan (1)

Hanscom Air Force Base, Mass.
Codes: AFCCDD/CCSEI-1
Attn: Capt. Long (1)

Jansky & Bailey, Inc.
1339 Wisconsin Avenue, N.W.
Washington , D.C.
Attn: Mr. F.T. Mitchell, Jr.
         Contract N178-7604 (1)

Lockheed Aircraft Corporation
P.O. Box 504
Sunnyvale, California
Attn: Missile Systems Div.
         Dept. 62-20,
         Mr. I.B. Gluckman (1)
Attn: Missiles and Space Div.
         Dept. 81-62,
         Mr. E. W. Tice (1)
Attn: Missiles and Space Div.
         Dept. 81-71
         Mr. R. A. Fuhrman (1)

McCormick Selph Associates
  Hlister, California
Attn: Technical Librarian (1)

Midwest Research Institute
425 Volker Boulevard
Kan as City, Missouri
Attn: Security Officer (1)

RCA Service Company
Systems Engineering Facility
Government Service Department
838 N. Henry Street
Alexandria, Virginia
Attn: Mr. C. M. Fisher (1)

Sandia Corporation (Div. 1262)
Albuquerque, New Mexico
Via: FCDASA (1)

University of Denver
Denver Research Institute
Denver 10, Colorado
Attn: R. R. B. Feagin (1)

U.S. Flare Division Atlantic
   Research Corp.
19701 W. Goodvale Road
Saugus, California
Attn: Mr. N. E. Eckert, Head,
         R&D Group (1)

Vitro Laboratories
14000 Georgia Avenue
Silver Spring, Maryland
Attn: Miss C.M. Jaques, Librarian (1)

Welex Electronics Corp.
Solar Building, Suite 201
16th and K Streets, N.W.
Washington 25, D.C. (1)

North American Aviation, Inc.
Communication Services
4300 E. 5th Ave.
Col. 16, Ohio (1)

e